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Integration of Khartoum Cadastral Information into State and Sudan Base Map

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ABSTRACT

The study aims to evaluate and improve Aboadam locality-Khartoum State, digital cadastral map layer and to look into its integration possibility with Khartoum State Basemap as well as Sudan National Basemap system. To achieve this objective many approaches have been attempted based on the knowledge of the process steps used to develop the dataset together with the related errors. The approach to estimate the positional accuracy of the cadastral dataset derived from the digital cadastral land maps were reviewed. Then positional data was collected by the aid of GNSS to coordinate the cadastral maps and to apply the geo-references process to fit it with the previous Khartoum aerial photography mapping.

KEYWORDS: *GNSS, UTM, Khartoum Basemap, Sudan National Basemap, Cadastral layer, georeferencing, Map Conversion*

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1. INTRODUCTION

Cadastre can be considered as a parcel based, and up-to-date land information system containing a record of properties in land. Cadastral maps are being used as tools for the administration of lands in dealing with day-to-day revenue and development activities in the State. This study concerns with the evaluation and integration of Khartoum state cadastral map with the Khartoum Basemap (developed by the general Survey Directorate of Khartoum State) and Sudan National digital Basemap (developed by the federal Sudan Survey Authority). So, in this study, assessment of Khartoum cadastral information has been done, in which all land information of Khartoum state shall be brought in one network by unifying the information system for at least the most relevant departments (survey, planning, land, and registration). The accuracy and usability for such a process can be done through the use of GIS software.

The problem that led to this study, is that most of the cadastral maps in Khartoum state are still in a hard copy format or digitally available in different coordinate systems. In such situation this kind of information cannot be used in GIS applications or to carry out data sharing and integration processes, and even GNSS techniques [2] cannot be applied directly, for cadastral surveying, demarcation and setting out. The steps followed can be outlined as: -

- Conducting a need assessment of cadastral information system.
- Evaluation of Khartoum land layer in terms of accuracy and usability.
- Studying the possibility of integrating the cadastral data sets with Khartoum state base map and Sudan National base map, through map conversion processes.

The methodology used to meet the above objectives is mainly composed of the following steps: firstly, conducting an assessment of digital cadastral maps, through comparison between digital cadastral land layer and Khartoum state base map, and secondly by evaluating the digital cadastral land layer in terms of accuracy and usability, then by using GNSS measurement to geo-reference the cadastral land layer of Aboadam, followed by its comparison again with Khartoum state base map (after georeferencing) and Sudan National base map.

2. Digital Cadastral Maps:

As well known, Cadastre can be a parcel based, as an up-to-date land information containing a record of properties in land. So cadastral maps show the relative location of all parcels in a given locality, State or a village. In Sudan, they are commonly range from scales of 1:1000 to 1:5000. information in the textual or attribute files of the cadastre, such as land value, ownership, or use, can be accessed by these unique parcel numbers as usually shown on the cadastral maps and land information systems.

Cadastral maps are essential tools for the land administration, in dealing with day-to-day development activities in any locality. In most cases in Khartoum State, these maps have lost their relevance since the maps are outdated over a long time, and their original ground control were lost or destroyed. This study, meant, also, to encourage Khartoum State localities to update their cadastral information, so that transformation/changes of ownership, size etc., can be recorded and managed easily, in an orderly manner for documentation and further use. Sonjay Mondal [9], outlined the role of the professional land surveyor and his relationship with other entities involved in land management, land information systems and the cadastre. The study realized that, most of cadastral information in Khartoum are still paper based maps, which is very difficult to store and use in the digital environments of today. So, the study started with the digitization of existing Land Record (LR) sheets of the study area, assessing the absence of the formal cadastral layout design effects in the study area, as well as the ways to implement proper digital sustainable development and control on the part of government agencies.

In the past, the Khartoum cadastral maps are prepared by using chain and tape measurements and plane tables and theodolites surveys. Now a days the cadastral maps are being prepared using Electronic Total station (EDM), aerial photography and space based remotely sensed high-resolution satellite images, GIS and GNSS techniques adopting the concept of large-scale mapping of today. So, the study also concerned with how to link old cadastral maps with the newly generated ones.

Figure 1: shows an example of Khartoum Land Use Layer

In Khartoum State, old cadastral land layer has been developed to show the boundaries of subdivisions of land, using the bearings, the lengths and the areas of the individual tracts, for the purposes of describing and recording ownership. A cadastral map may also show culture, drainage, and other features relating to the value and use of the land [3].

2.1. Components of a Digital Cadastral Mapping System

A digital cadastral mapping system of today, should have the following components, [9]:

- Reference to a geodetic control network.
- Current base map layer.

- A cadastral layer delineating all real property parcels.
- A unique parcel identifier assigned to each parcel .
- A means to tie spatial data to attribute data (ownership and parcel characteristic files)

Additional layers of interest, such as locality or municipal boundaries, zoning, soil types, and flood plains are to be taken into consideration, so that, the cadastral digital map [8], is to be consisted of inventory of property parcels indicating parcel boundaries and unique parcel identifier, register of interests (rights, restrictions, responsibilities) and interest holders (e. g. owners). This means that, the cadastral information on a computer system has to determine cadastral identifier and links, location; boundary, land use, components distinguishing different functions or land use; land purpose assigned in the local spatial development plans and locality attributes of a particular real estate [7].

Don Grant [1], highlighted the importance of the rules for cadastral survey, that, to specify how the spatial extent of interests in land must be defined and described, as well as the accuracy requirements for non-boundary marks on a survey as shown in Table.1. While the accuracy requirements for each class of boundary point on a survey are as given in Table.2. Don Grant [1] accuracy requirements were adopted in this study.

The horizontal and vertical accuracy between	Must not exceed
all new and old non-boundary marks …	$\sqrt{0.025^2 + (dis * 0.0001^2}$m, at the 95 % confidence level
any two non-boundary marks, including adopted non-boundary marks	0.03 m + distance between the points *0.00015m
any two new or old non-boundary marks	0.50 m

Table (1): Accuracy of non-boundary marks

Boundary class	The horizontal and vertical accuracy between…	Must not exceed
A	all boundary points, other than adopted points, and irrespective of these points being marked or not…	$\sqrt{0.04^2 + (D * 0.0001)^2}$m, at the 95 % confidence level
	any boundary point and any other boundary point, including adopted points and irrespective of these points being marked or not…	0.06 m + D × 0.00015 m
B	all boundary points, other than adopted points, and irrespective of these points being marked or not…	$\sqrt{0.20^2 + (D * 0.0004)^2}$m, at the 95 % confidence level
	any boundary point and any other boundary point, including adopted points and irrespective of these points being marked or not…	0.30 m + D × 0.0006 m
C	all boundary points, other than adopted points, and irrespective of these points being marked or not…	$\sqrt{0.60^2 + (D * 0.002)^2}$m, at the 95 % confidence level
	any boundary point and any other boundary point, including adopted points and irrespective of these points being marked or not…	1.00 m + D × 0.003 m
Where D is the horizontal distance between the points in metres in the case of horizontal accuracy, and the vertical distance between the points in the case of vertical accuracy.		

Table (2): shows the accuracy of straight-line boundaries and arc boundaries

3. Khartoum Basemap

The Khartoum State Basemap produced from aerial photography, conducted by the Ministry of Urban Planning represented by the General Survey Directorate for performing aerial photography of Khartoum State in 2008, and the project was completed in 2009. The project has covered the entire state with the accuracy 10 cm in developed areas and 40 cm on other areas. The aerial photography was performed with 30% lateral overlap and 60%frontal overlap. Ground Control Points (GCP) distributed with the grid of about 20 km, based on WGS84 UTM datum. The Khartoum State base map is a vector map (Fig.2) and orthophoto, its contents are identified by

the Survey Directorate, which is the entity responsible for Basemap creation, production and updating in Khartoum State [5].

Various implications of Sudan base maps can be defined including:

- Topographic Mapping: A topographic map is a type of map characterized by large-scale detail and quantitative representation of relief, usually using contour lines and DTM. A topographic map contains both natural and man-made features., and is typically published as a map covering a township, a city, a country or an entire State. For Khartoum State, the topographic maps are essential for design and engineering applications and for provision of many kinds of services. But in practice, currently, there was a very limited use of the Basemap in Khartoum, unfortunately many of Sudan State government departments are producing their own Base maps which are not standardized.

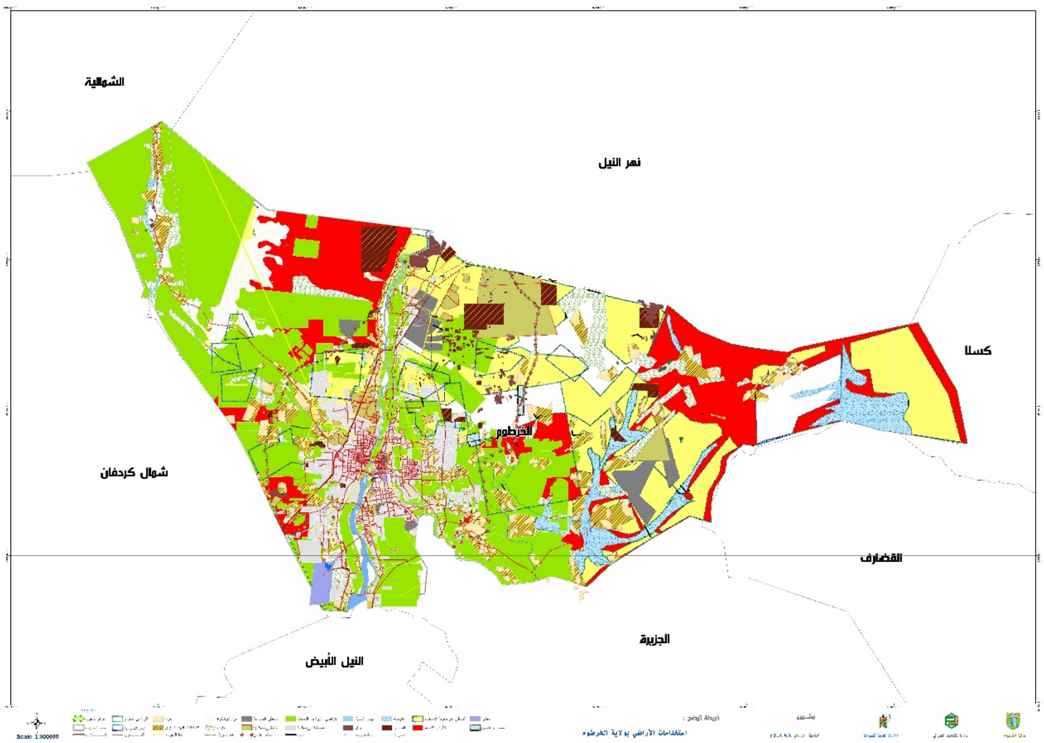


Figure 2: Sample of Khartoum State Basemap

- Base Map Update: Base Map update is the process where a base map layer is maintained and updated on a regular basis to reflect the current state of the infrastructure in an area. In Sudan Basemap update is currently produced from aerial photogrammetry processes and ground topographic surveys. Satellite imagery can be used for completeness, detecting and checking the missing features. Base map information is to provide the spatial frame of reference for all other geospatial data. These may include geodetic control, topographic and bathymetric contours, spot elevations, planimetric features, coordinate grids, and similar information [8]. The Khartoum Basemap includes the following data themes: Geodetic Framework, land properties, elevations, hydrography, imagery and remotely sensed data, scanned maps, planimetric features, structures etc.

- Positional Accuracy: Positional (horizontal and vertical) accuracy is considered to be of crucial importance, as there is a relationship between this and scale, whereby the level of accuracy applied often increases at larger scales. As well of equal or greater importance to accuracy is the completeness, both in spatial and descriptive terms. Spatial completeness refers to whether or not a data set covers the entire territory that it ought to, in addition to ensuring that all features within that territory have been captured. Descriptive or attribute completeness typically relates to ensuring that all information for a given feature has been recorded.

- Map Projections and Datums: Map projections are the systems used to represent all or part of the earth's spherical surface as a flat map. A GIS can project units of measurement for a geodetic coordinate system (such as latitude and longitude) into a flat, planar coordinate system using a map projection. Both raster and vector data structures utilize UTM map projection that store data in E, N plane coordinate system (This creates the scale factor issues in plane surveying, setting outs, and GIS application in Khartoum State). As well known in surveying and geodesy, a datum is a set of reference points on the earth's surface against which position measurements are made [4], and (often) an associated model of the shape of the earth

(ellipsoid) to define a geographic coordinate system. Traditionally, horizontal datums are used for describing a point on the earth's surface, in latitude and longitude or another coordinate system. Vertical datums measure elevations or depths, again relative to a reference such as mean sea level, calculated ellipsoid, or other. Here in Khartoum State the International Terrestrial Reference Frame epoch 2000.0 (ITRF2000.0) adopting WGS 84 ellipsoid was recently being utilized.

The base map is available and organized according to accepted specifications and mapping standards, covering the entire Khartoum State territory showing land use, residential areas, agricultural areas, main roads and the river Nile. In general, the base map meeting the user requirements, and readily available and accessible for government departments, individuals and private sector organizations. The updating of spatial data usually done based on the field survey works, and the authors recommended that, updating is to be based on State wise transactional activities in the near future.

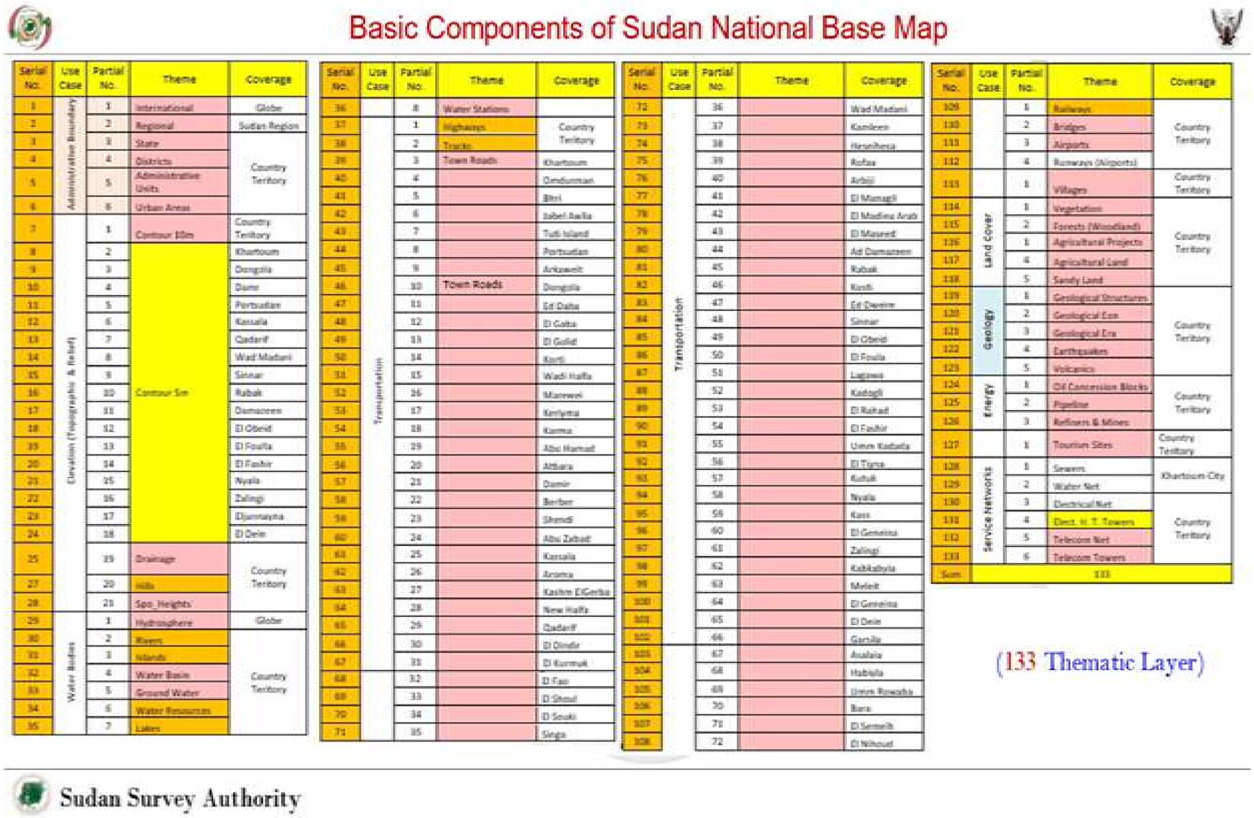
The current main challenges for Khartoum State in terms of spatial data infrastructure development will include non-organized data acquisition, data quality, standardization, policies, data sharing and integration. The Survey Directorate **data input** subsystem allows the staff users to capture, collect, and transform spatial and thematic data into digital form. The **data storage** and retrieval subsystem organize the data, spatial and attribute, in a form which permits it to be quickly retrieved by the staff user for analysis, and permits rapid and accurate updates to be made to the database. This component usually involves use of a database management system for maintaining attribute data. The **data manipulation and analysis** subsystem allow the user [9], to define and execute spatial and attribute procedures to generate derived information. Here the authors are well aware that Leading State organizations are actively taking the initiative to evolve from a data and process driven enterprise framework to a user driven framework. The user driven framework supports internal and external user involvement with a focus on improving and enhancing business processes and bi-directional sharing of geospatial information.

As mentioned, this study concerns with the evaluation and integration of Khartoum state cadastral map with the state base map and Sudan survey digital base map. So, the Khartoum cadastral information is assessed, followed by unifying the information system for relevant departments (survey, planning, land, registration) storing, all land information of Khartoum state in one network by the aid of GIS software.

4. Sudan Survey Authority base map.

Sudan Survey Authority Base map is the Sudan National Basemap adopted for the entire country area, showing certain fundamental information, and provides location references for features that do not change often such as boundaries, rivers, buildings, lakes and highways. So, the National Basemap contains basic survey control and reference framework for integrating all of the other map features of a particular area.

The Sudan base map project initial by the National Information Center (NIC) in early 2000s in such a way that, the Basemap is federal strategy designed to maximize the value to the public of any given geospatial data. The data collected from various government entities of Sudan, for the Base map through the use of the existing spatial data and the missing data have been reviewed, checked. The mapping system specification has been analyzed, and documented. This will include both data and processing modules used for digitizing, analog data, digital data, high spectral and high spatial image and aerial photo. The main components of Sudan National Basemap [4] are summarized in Figure.3.


Basic Components of Sudan National Base Map

Serial No.	Use Case	Partial No.	Theme	Coverage
1	Administrative Boundary	1	International	Globe
2		2	Regional	Sudan Region
3		3	State	Country Territory
4		4	Districts	
5		5	Administrative Units	
6		6	Urban Areas	
7	Elevation (Topographic & Relief)	1	Contour 10m	Country Territory
8		2	Contour 5m	Khartoum
9		3		Dongola
10		4		Damr
11		5		Portsudan
12		6		Kassala
13		7		Qadarif
14		8		Wad Madani
15		9		Sinnar
16		10		Rabak
17		11		Damazeen
18		12		El Obeid
19		13		El Foulla
20		14		El Fashir
21		15		Nyala
22		16		Zalingi
23		17		Eljannayna
24		18		El Dein
25		19	Drainage	Country Territory
27		20	Hills	
28		21	Spo_Heights	
29	Water Bodies	1	Hydrosphere	Globe
30		2	Rivers	Country Territory
31		3	Islands	
32		4	Water Basin	
33		5	Ground Water	
34		6	Water Resources	
35		7	Lakes	
36		8	Water Stations	
37	Transportation	1	Highways	Country Territory
38		2	Tracks	
39		3	Town Roads	Khartoum
40		4		Omdurman
41		5		Bhri
42		6		Jabel Awlia
43		7		Tuti Island
44		8		Portsudan
45		9		Arkaweit
46		10	Town Roads	Dongola
47		11		Ed Daba
48		12		El Goba
49		13		El Golid
50		14		Korti
51		15		Wadi Halfa
52		16		Marewei
53		17		Kerlyma
54		18		Karma
55		19		Abu Hamad
56		20		Atbara
57		21		Damir
58		22		Berber
59		23		Shendi
60		24		Abu Zabad
61		25		Kassala
62		26		Aroma
63		27		Kashm ElGerba
64		28		New Halfa
65		29		Qadarif
66		30		El Dindir
67		31		El Kurmuk
68		32		El Fao
69		33		El Showl
70		34		El Souki
71		35		Singa
72		36		Wad Madani
73		37		Kamleen
74		38		Hesaihesa
75		39		Rofaa
76		40		Arbiji
77		41		El Managil
78		42		El Madina Arab
79		43		El Maseed
80		44		Ad Damazeen
81		45		Rabak
82		46		Kosti
83		47		Ed Dewim
84		48		Sinnar
85		49		El Obeid
86		50		El Foulla
87		51		Lagawa
88		52		Kadogli
89		53		El Rahad
90		54		El Fashir
91		55		Umm Kadada
92		56		El Tiyna
93		57		Kutum
94		58		Nyala
95		59		Kass
96		60		El Geneina
97		61		Zalingi
98		62		Kabkabyia
99		63		Meleit
100		64		El Geneina
101		65		El Dein
102		66		Garsila
103		67		Asalaia
104		68		Habiala
105		69		Umm Rowaba
106		70		Bara
107		71		El Semeih
108		72		El Nihoud
109		1	Railways	Country Territory
110		2	Bridges	
111		3	Airports	
112		4	Runways (Airports)	
113		1	Villages	Country Territory
114	Land Cover	1	Vegetation	Country Territory
115		2	Forests (Woodland)	
116		3	Agricultural Projects	
117		4	Agricultural Land	
118		5	Sandy Land	
119	Geology	1	Geological Structures	Country Territory
120		2	Geological Eon	
121		3	Geological Era	
122		4	Earthquakes	
123		5	Volcanics	
124	Energy	1	Oil Concession Blocks	Country Territory
125		2	Pipeline	
126		3	Refiners & Mines	
127		1	Tourism Sites	Country Territory
128	Service Networks	1	Sewers	Khartoum City
129		2	Water Net	
130		3	Electrical Net	Country Territory
131		4	Elect. H. T. Towers	
132		5	Telecom Net	
133		6	Telecom Towers	
Sum	133			

(133 Thematic Layer)

Sudan Survey Authority

Figure.3: shows the main components of Sudan National Base map

Figure.4 illustrated the Sudan National Base Map land use layer emphasizing the settlements, government institutions, industrial and agricultural areas.

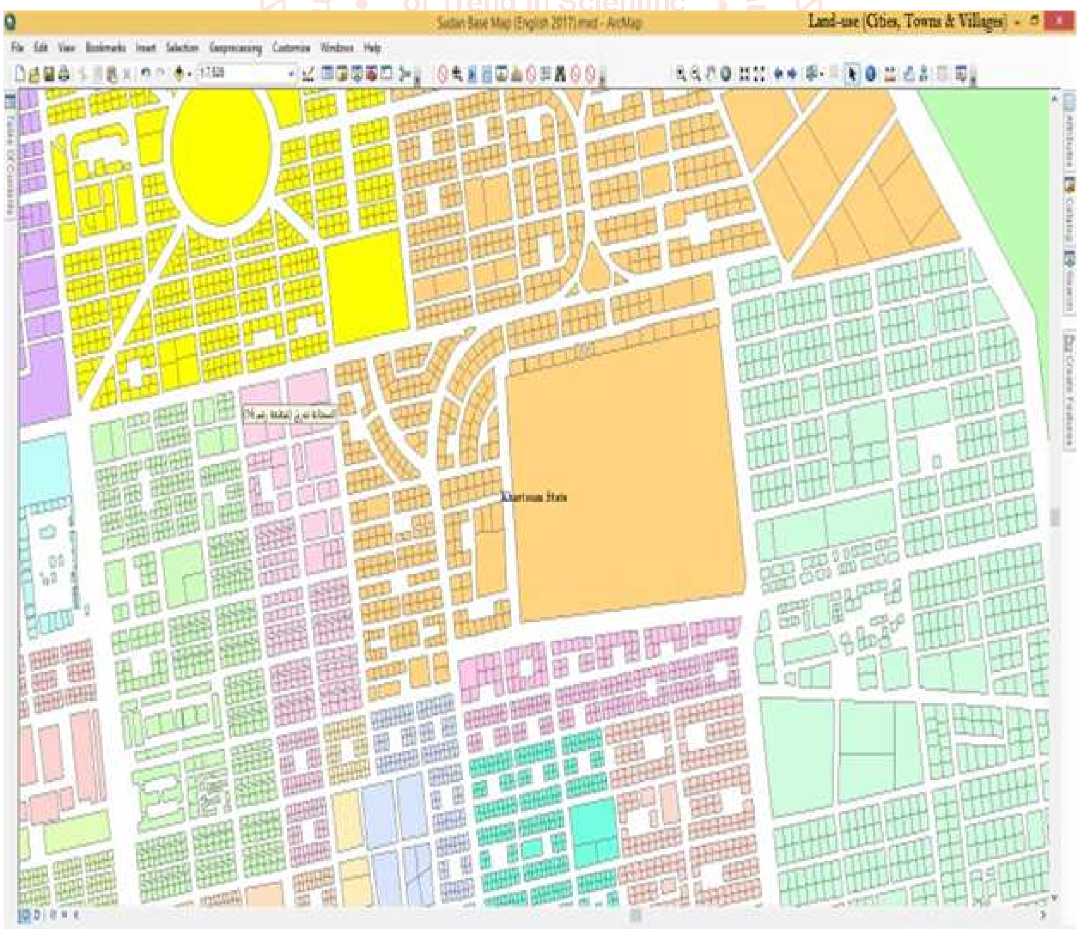


Figure.4: shows an example of National Basemap Land Use layer in Khartoum area

5. Cadastral Layer and Base maps Conversion Activities:

The authors use, both old geodetic control networks (in which the old cadastral surveys and data collection was based on Adindan datum) and the new Khartoum geodetic control network (ITRF2000.0) used for the state Basemap and ortho photo production and here also has been used as a base for cadastral data conversion. The existing new Khartoum geodetic network is established to meet the various local needs for spatial data and geomatics activities. These networks are considered to be as a basis, as well as a development guide for Khartoum government and private sector organizations in the fields of spatial data and mapping information in the entire State territory. The old cadastral data may adopt and based on different datums. Some of the existing old control stations may be non-homogeneous, unadjusted and have many limitations in terms of spatial data applications. While the ITRF2000.0 geodetic network is established and tied to the ITRF system, containing well-distributed geodetic control stations. The transformation parameters between the ITRF2000 and the old cadastral datum/s were computed. The assessment was carried out to present the quality of both old and newly established geodetic networks, outlining their relationship and mapping conversion methods. Serious problems and limitations related to datum transformation in GNSS operations, mapping and spatial data conversion processes were indicated and discussed before the start of the Khartoum cadastral data and Basemap conversion process.

The assessment of the quality of the geodetic networks consisted of an intensive checking of the GNSS results, the quality of the individual campaigns, the consistency of GNSS observations, and the ties between the old networks and ITRF2000.

An alternative transformation model for non-homogeneous spatial data conversion is also indicated. Several factors have to be taken into consideration during the network design and data conversion processes, including the technical specifications, the method of observation, the resources to be deployed during the observation, the geometrical strength, and the tie to the primary network, all found to influence the final results and the method of data conversion.

5.1. Transformation of Khartoum Basemap Spatial Data:

Spatial data conversion was carried out to transform the existing homogeneous/non-homogeneous projected mapping and cadastral data of Khartoum into the newly established Khartoum Spatial Reference System (i.e., ITRF2000.0). The transformation was under taken in such a manner that the statistical errors were to be kept to a minimum. The implementation of the converted UTM-ITRF2000 and Sudan National Basemap WGS84 graphical datasets and the associated control networks assisted in carrying out spatial data conversion activities as well as providing a reference for continued development. Geomatics activities using modern surveying and mapping technologies based on a homogeneous reference system were applied across the entire State to update and maintain the spatial database and to efficiently control further engineering and mapping development projects. The transformation parameters between the old geodetic coordinate systems in Khartoum and the new geodetic datum (ITRF2020) are determined. Of course, reliable results for the transformation parameters can only be expected if the coordinates of both systems are reasonably homogeneous. The determination of transformation parameters for the entire Khartoum State was done using Helmert Transformation, applying seven and four-parameter transformation. For non -homogeneous data, this was followed by the division of the State into zones based on the residual analysis included in the derivation of the transformation parameters. In consideration of the varying nature of the control points in Khartoum, a weighing scheme was devised to take into account the accuracy of the control points or more precisely the degree of confidence of their accuracy. Weights were allocated based on the relative accuracy of the new coordinates. The overall analysis of the transformation residuals performed using the geodetic control stations. To obtain a better indication of where the regional zone boundaries are to be located, the entire existing control points were used to derive a set of transformation parameters, together with a set of residuals. These residuals gave an indication on possible homogeneity of control point region, since the transformation approach is free of manipulating geometrical constraints. The zonal transformation parameters for each zone were performed for all non-homogeneous spatial data as well as Khartoum cadastral map features.

5.2. Multi -dimensional transformation For Spatial Data Conversion

It should be noted here that the authors, intended to highlight the whole strategy of spatial data transformation and the identification of complete set of work packages to be used as follows:(a) Densification of ground control points. (b) Deriving a continuous horizontal transformation. (c) Spatial data collation and data acquisition. (d) Transformation of archive data.

An alternative strategy in transforming the horizontal coordinates of the existing Khartoum archive data would be to derive a multi-dimensional transformation that varies its parameters gradually across the whole of the State. This can be done in the following way:

A. The first step is to carry out a single similarity (conformal) transformation to all data across Khartoum State. This will result in residuals in easting and northings values.

B. These residuals are to be treated as "extra" corrections that are to be applied to the archive data to bring them in line with the new coordinate system. They consist of a set of "east" corrections and a set of "north" corrections.

C. The values of each set of corrections can be considered as a set of values with spatial distribution. A standard GIS or mapping package can be used to construct a "correction surface" to be applied for each coordinate, in exactly the same way that it is used to generate a "terrain surface" from a series of spot heights.

D. By constructing a Triangulated Irregular Network (TIN) model or similar using points where the transformation is known, the transformation at unknown points can be derived from a simple interpolation procedure.

This approach has the advantage that the transformations applied are smoothly varying over the whole State, rather than having edge matching applied in a narrow transition area between zones. In addition, it must be recognized that the actual error sources are not themselves necessarily changing smoothly across the State or Locality. It is clear that sudden changes can occasionally occur, here it would therefore be concluded that the "TIN approach" is generally capable of delivering coordinate conversions with accuracy in the Khartoum State 0.25–0.50m, but some gross errors may still exist after transformation.

5.3. Khartoum Existing Base Map Data Migration:

Under the scope of the study, it wasrequired to perform data migration on one locality (Jebel Aulai) using Khartoum Base Map data, as follows: The Vector Base Map, including Manmade Buildings and Structures, roads, drainage, vegetation and utility infrastructure features, which are available in the UTM- zone 36N coordinate system based on WGS 84 Reference Ellipsoid and ITRF2000 reference frame.

The following were performed in the study area of Jebel Aulia locality:
1. All Base Map data are fully topologically cleaned prior to migration.
2. All Base Map data are fully checked by field observations for quality control prior to migration.
3. All migrated Base Map data are found to be fully conform with the Khartoum State common data content standards.
4. All migrated Base Map data were delivered to a production Server database.
5. Program routines were developed, which can be used by Khartoum on a daily/regular basis to update the Base Map data.

The authors proposed that the data migration of Khartoum Geospatial/Base Map data should be done as in the above four steps. With the consideration of all required logistics, equipment, hardware and software, required to perform the mapping Conversions. The following activities are suggested to be performed for Khartoum legacy data conversion, table.3:

	Activity	Description
1	Data Collection:	old and new geodetic Control Points coordinates and benchmarks and geoid model data
		Basemap and all Khartoum State legacy data
2	Transformation parameter computation	Computation of transformation parameters between the * New and all old horizontal datums * Old and new benchmarks heights/ vertical datum
3	Data Conversion	Basemap and all localities legacy data conversion to the new reference system
4	Field work	GNSS features Observation
5	Assessment of conversion process	Computation of errors and residuals for coordinates

6	Judgement	In 5, it should be judged that, the data accepted to be converted as one unified transformation approach or it requires further analysis.
		If errors and residuals are not acceptable in 5, then blocks or zones for spatial data are to be specified for the computation of transformation parameters as in 2 above for each zone or block.
7	Blocks or zone data conversion	Basemap and legacy data conversion should be made for each block or zone separately
8	Edge matching	Carry out edge matching processes between neihbouring zones.
9	Reassessment of data conversion	Assessment of the converted blocks or zones against GNSS features coordinates collected as in 3 above.
10	Technical Document	A technical report should be prepared, documenting all the steps and the quality of the Khartoum Basemap and legacy data conversion process.

Table.3: Shows the steps followed for Cadastral Layer conversion

Study Area data conversion Processes

Aboadam study area, located south of Khartoum State in Jebel Aulia locality with an area of about 6,500 km2 and lies between the north eastings (E = 446312m), the south eastings (E= 444505m), the west northing (N= 1711419m) and the east northings (N=1714812m) of UTM local coordinates as illustrated in figure.5. In the study area of Aboadam, the cadastral layer was divided into 14 blocks, each one containing properties with parcels numbers and services, the same as that used in the establishment of Aboadam digital map, in which, each property has its own random local coordinate system. During the assessment stage [10], it appeared that, the land layer of Aboadam has some mistakes, occurred in the planning drawings. So, the study is focused in the ways of enhancing these drawings, taking into consideration their original plan sheets that were established by field surveys and drawn by using AutoCAD software at 1:1000 scales. In this study, 12 cadastral blocks were investigated and compared with the existing Khartoum state base map and Sudan National Basemap and tested for its spatial accuracy.

Figure.5: Shows the boundary of the study Area (Source Google Earth)

The procedures applied for evaluating the positional accuracies of the cadastral plots based on the use of GNSS for cadastral surveying taking into the account, the limitations of the equipment to be used, the observational procedures, the processing techniques, the geodetic reference system and map projection, together with the suitable practices to ensure measurement redundancies and basic statistical analysis. The Features points (FPs) coordinates of Aboadam were collected by using Global Navigation Satellite System (GNSS) instrument in static mode [2]. The FPs referenced to Khartoum State control network based on ITRF2000 adopting WGS84 ellipsoid (1/f= 1/298.257, a= 6378137) using Leica Viva 10 receivers, and the data processing's were made by

Leica Geo-office software. Based on the known ground control point, some points were measured and used for geo-referencing cadastral layer of the study area. Then 10 points were selected from cadastral layer after the geo-referencing process has been completed, to evaluate and assess the Khartoum base map and Sudan base map coordinates. In this process, the geometrical distribution of the points was taken into consideration. The AutoCAD program was used for 2-D and 3-D design of Khartoum Cadastral layer. A Geographic Information System is also used to design, store, retrieve, manage, display, and analyze all types of geographic and spatial data of the Cadastral layer as well as the Khartoum and Sudan National base maps. This due to the fact that, the GIS software encompasses abroad range of applications which involve the use of combination of digital maps and geo-referenced data. So, GIS software was used to geo-reference the cadastral map of study area after the AutoCAD plans design. The actual steps followed in the process for georeferencing the Cadastral layer are as follows [10]:

A. Ground survey of Aboadam for the collection of FPs coordinates using GNSS instrument: - In this step, the coordinates of the FPs were collected using GNSS instruments, with baselines of about 4 kms, in static mode of observation based on Khartoum known ground control points. The cadastral map layer of the study area was geo-referenced using the ground control points and some known Ground features points (FPs) for each block in the study area.

B. Digital land layer: **-** In this step, the cadastral land layer of Aboadam was assessed, and it appeared that, some mistakes were occurred in the drawings. These mistakes were corrected by using original plan sheets, and enhancement for each block of the study area by using AutoCAD software (Figure.7). Each block of the study area has its own random local coordinate system. The cadastral map layer for Aboadam study area was converted from AutoCAD (DXF) file format to geo-database format in GIS software, after the enhancement.

C. Geo-referencing of cadastral land layer: - As, the cadastral land layer of Aboadam at 1:1000 scales has been collected and the drawing were generated from paper sheets by using AutoCAD software (Figure.6). The geo-referencing has been performed by using ground features points (FPs), which were collected in the field. Individual blocks of the cadastral land layer data after geo-referencing are converted to feature class into geo-database and associated with the other layers in the area (Figure.8).

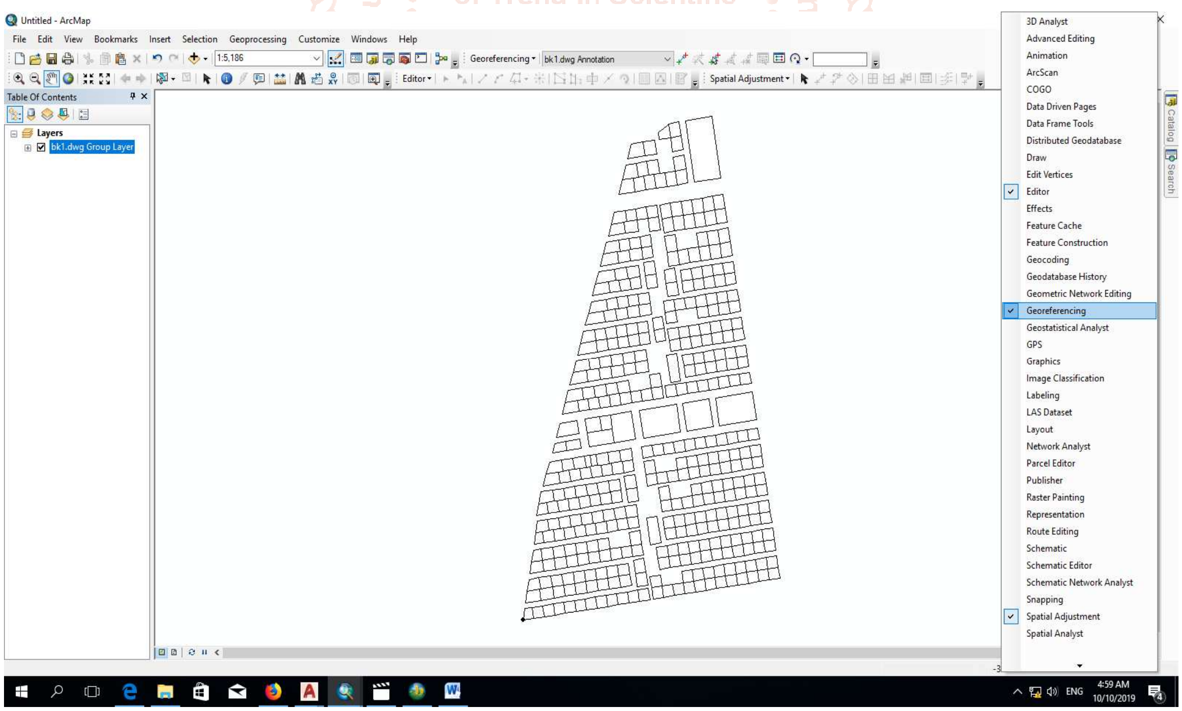


Figure.6: Cadastral Layer before Geo-referencing

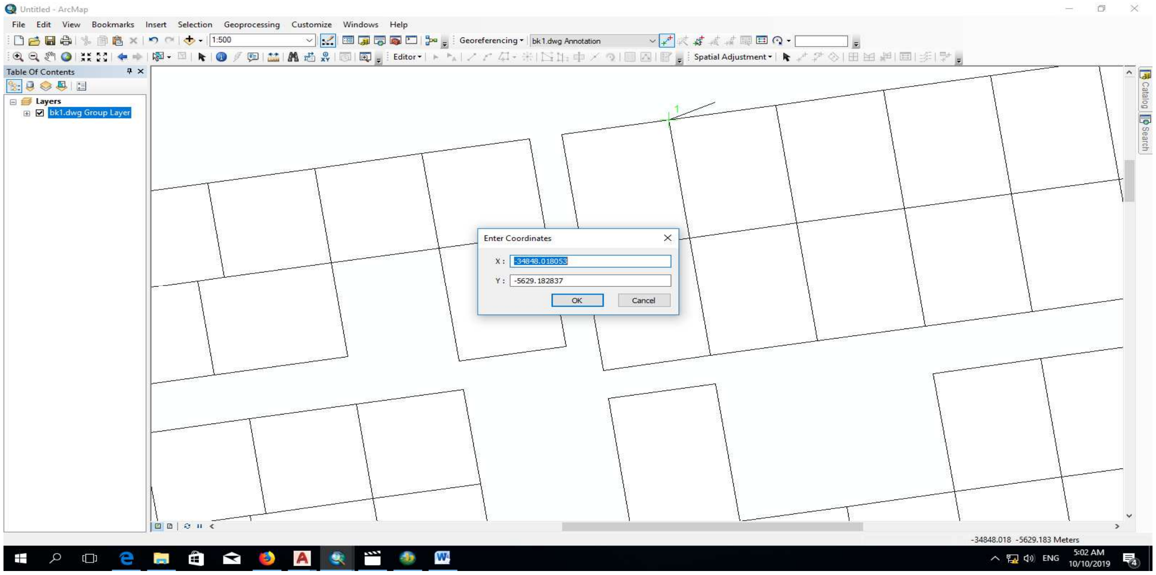


Figure.7: AutoCAD generated features for Geo-referencing

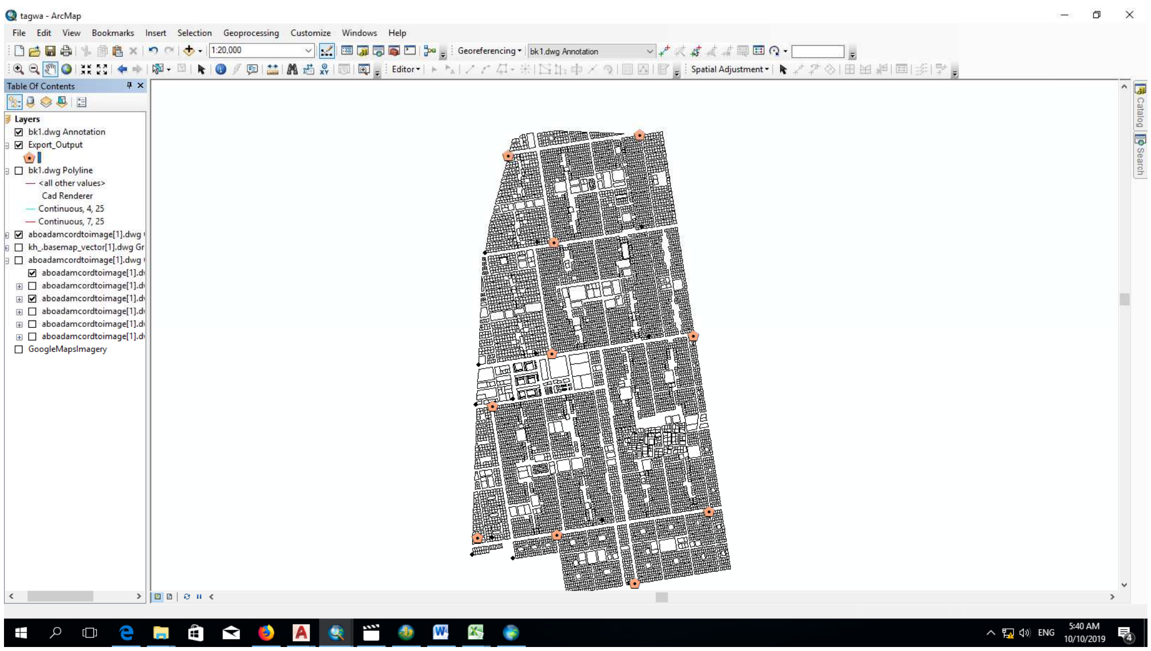


Figure.8: Georeferenced Cadastral Layer of the study Area

The topology cleaning processes has been made, defining the geometric relationships between the features (point. line. polygon), and considered to be as spatial correction to modify and evaluate the database and correct errors through an organized set of rules. The topology work turned it into a class feature inside the dataset feature, and it turns into georeferenced database.

6. Comparison between converted cadastral, Khartoum Basemap and Sudan Basemap:

Khartoum state base map and Sudan National Basemap are considered for the same location. The comparison has been made between the coordinates of the cadastral land layer before and after geo-referencing process. Then, the comparison between the features coordinates of the cadastral land layer and Khartoum state Basemap features coordinates was made to assess positional accuracy for Aboadam cadastral layer. Also, the same process has been made for the comparison between the coordinates of the land layer and Sudan National Basemap coordinates, to assess positional accuracies of the cadastral layer relative to Sudan Basemap. The analysis and computations of the results to asses and evaluate the cadastral land layer to both Khartoum state and Sudan National Basemaps. This process helped in the evaluation of Aboadam cadastral layer in terms of accuracy. Finally, an evaluation was made to evaluate the geo-referenced cadastral land layers by using GNSS receivers' observations.

In this kind of studies, the positional accuracy can be used as an indicator or a measure of how a spatial feature is accurately positioned on the map or layer, with respect to its true position on the ground. Positional accuracy of

features location, are normally measured as a root mean square error (RMSE). The RMSE error and the horizontal shifts were computed.

RMSE(x) = $\sqrt{1/n(x - X)2}$ (1)

RMSE(y) = $\sqrt{1/n(y - Y)2}$ (2)

Where: x, y are the coordinates of the ith check point in the dataset, and X, Y are the coordinates of the ith reference point, and n is the number of check points.

Horizontal shift at a point is defined as:

RMSE (error) =$\pm\sqrt{RMSE(X)2 + RMSE(Y)2}$ (3)

While the mean errors are computed from:

X = $1/n \sum_{i}^{n} xi$ (4)

Where: xi is error in the specified direction, n is the number of checkpoints (from 1 to n).

The standard deviation, Sx, is computed from:

Sx = (1/ (1-n) $\sum_{i}^{n}(X - x)2$ (5)

Where: xi is the error in the specified direction, X is the mean error in the specified direction, n is the number of checkpoints tested, i is an integer ranging from 1 to n.

The above formulae were used to compare the coordinates of the cadastral land layer features and to estimate their positional accuracy in meters.

6.1. Assessment of the Cadastral layer Accuracy Before georeferencing

Assessment of the accuracy of the cadastral Land layer of Aboadam before geo-referencing as it compared with the Khartoum state Basemap, 10 points were selected for this comparison process. The differences in ΔEast and ΔNorth coordinates, standard division and the horizontal shifts are computed and shown in table.4.

point	Features coordinates (before geo-referenced)		Features coordinates in Khartoum state base map		Residuals		Horizontal shift error
	East (m)	North (m)	East (m)	North (m)	Δ East (m)	Δ North (m)	RMSE (m)
1	444773.0345	1714399.4	444769.218	1714396.768	3.817	2.632	4.636065
2	445742.6536	1714550.249	445743.026	1714548.235	-0.372	2.014	2.04814
3	446138.371	1713050.965	446144.077	1713052.008	-5.706	-1.043	5.800542
4	445096.1045	1712919.615	445097.078	1712920.134	-0.973	-0.519	1.103206
5	444652.9129	1712529.289	444656.707	1712527.078	-3.794	2.211	4.391323
6	444545.5751	1711550.725	444546.815	1711549.206	-1.240	1.519	1.960794
7	445130.0046	1711568.538	445130.697	1711568.295	-0.692	0.243	0.733803
8	446255.98	1711746.806	446256.539	1711745.213	-0.559	1.593	1.688233
9	445109.6087	1713751.591	445108.465	1713751.374	1.144	0.217	1.164104
10	445707.0223	1711209.232	445706.298	1711208.133	0.724	1.099	1.316211
Average					**-0.765**	**0.997**	**2.484**
StDv					**2.602**	**1.223**	**1.778**

Tables.4: Comparison between Cadastral layer (before georeferencing) and Khartoum Basemap

The Summary of the assessment of cadastral Land layer of Aboadam coordinates (before geo-referencing) and Khartoum state Basemap coordinates are given in table.5:

Particular	Δ East (m)	Δ North (m)
Number of point	10	10
Average of error	-0.765	0.997
Standard deviation	2.602	1.223
Min horizontal shift	0.734	
Max horizontal shift	5.800	

Table.5: Assessment of cadastral Land layer before georeferencing

Table.4. and table.5, illustrated that, the average positional shift ranges between -0.765 m in eastings and of 0.997 m in northings.

6.2. Assessment of positional Accuracy of cadastral layer after geo-referencing:

in this phase, positional accuracy was evaluated by comparing the cadastral Land layer coordinates (original after geo-referencing) and Khartoum state Basemap coordinates using the selected ten points' coordinates, table.4, assessment and comparison. The differences in ΔEast and ΔNorth coordinates, standard divisions and the horizontal shift were computed as in table.6.

point	Original(Geo-referenced)		Khartoum Base Map		Residuals		Horizontal shift
	East (m)	North (m)	East (m)	North (m)	Δ East (m)	Δ North (m)	
1	444769.665	1714396.918	444769.218	1714396.768	0.447	0.150	0.471497
2	445743.642	1714548.524	445743.026	1714548.235	0.616	0.289	0.680424
3	446143.966	1713052.044	446144.077	1713052.008	-0.111	0.036	0.116692
4	445096.403	1712920.321	445097.078	1712920.134	-0.675	0.187	0.700713
5	444656.329	1712527.770	444656.707	1712527.078	-0.378	0.692	0.78851
6	444545.864	1711548.166	444546.815	1711549.206	-0.951	-1.040	1.409255
7	445130.790	1711568.350	445130.697	1711568.295	0.093	0.055	0.108046
8	446256.813	1711745.060	446256.539	1711745.213	0.274	-0.153	0.313823
9	445107.547	1713752.769	445108.465	1713751.374	-0.918	1.395	1.669955
10	445706.494	1711208.288	445706.298	1711208.133	0.196	0.155	0.249882
Average					**-0.141**	**0.177**	**0.651**
St.Dv					**0.564**	**0.613**	**0.529**

Tables (6): Comparison between Cadastral layer (after georeferencing and Khartoum Basemap

The assessment of cadastral Land layer of Aboadam coordinates after georeferencing and the Khartoum State Basemap is summarized in table.7.

Particular	Δ East (m)	Δ North (m)
Number of point	10	10
Average of error	-0.141	0.177
Standard deviation	0.546	0.613
Min horizontal shift	0.108	
Max horizontal shift	1.669	

Table.7: Assessment of cadastral Land layer after georeferencing

Table.6. and table.7, illustrated that, the average positional shift ranges between -0.141m in eastings and of 0.177m in northings

6.3. Positional Accuracy of cadastral layer after geo-referencing and Sudan Basemap:

point	Original(geo-referenced)		Sudan Base Map		Residuals		Resultant
	East (m)	North (m)	East (m)	North (m)	Δ East (m)	Δ North (m)	
1	444769.665	1714396.918	444769.581	1714396.823	0.084	0.095	0.126777
2	445743.642	1714548.524	445743.233	1714548.336	0.409	0.188	0.450075
3	446143.966	1713052.044	446144.476	1713052.369	-0.510	-0.325	0.604645
4	445096.403	1712920.321	445095.845	1712920.324	0.558	-0.003	0.557807
5	444656.329	1712527.770	444656.375	1712527.644	-0.046	0.126	0.134374
6	444545.864	1711548.166	444546.201	1711549.063	-0.337	-0.897	0.958368
7	445130.790	1711568.350	445130.745	1711568.482	0.045	-0.132	0.138984
8	446256.813	1711745.060	446257.094	1711745.296	-0.281	-0.236	0.367302
9	445107.547	1713752.769	445108.364	1713753.030	-0.817	-0.261	0.858024
10	445706.494	1711208.288	445705.651	1711208.053	0.843	0.235	0.874923
Average					**-0.005**	**-0.121**	**0.507**
StDv					**0.508**	**0.337**	**0.319**

Table.8: Comparison between Cadastral layer (after georeferencing and Sudan National Basemap

The assessment of cadastral Land layer of Aboadam coordinates after georeferencing and the Sudan national Basemap is summarized in table.9.

Particular	Δ East (m)	Δ North (m)
Number of points	10	10
Average of error	-0.005	-0.121
Standard deviation	0.508	0.337
Min horizontal shift	0.126	
Max horizontal shift	0.958	

Table.9: Assessment of cadastral Land layer after georeferencing and Sudan National Basemap

Table.8. and table.9, illustrated that, the average positional shift ranges between -0.005m in eastings and of 0.121m in northings.

6.4. Final Checks for the accuracy of the georeferenced cadastral land layer:

Finally, two plots were randomly being selected to evaluate the geo-referencing, by comparing the accuracy of plot coordinates with the coordinates obtained from GNSS measurements. The cadastral Land layer of Aboadam coordinates and GNSS coordinates measured were compared, table.10. It can be seen that, errors range between 0.509 m to 0.249 m. the average of easting error was 0.135 m and northing, was 0.109 m.

point	Original (Geo-referenced) coordinates		GNSS measured coordinates		Residuals		Horizontal shift error
	East (m)	North (m)	East (m)	RMSE (m)	Δ East (m)	Δ North (m)	
343 bk 1	444954.5	1713767.776	444954.2596	1713767.609	0.2404	0.1669	0.292656
	444934.7672	1713764.575	444934.4971	1713764.536	0.2701	0.0394	0.272959
	444937.924	1713744.407	444937.57	1713744.773	0.354	0.3663	0.509403
	444957.566	1713747.753	444957.333	1713747.847	0.233	0.0937	0.251135
34 bk9	446197.618	1711735.832	446197.4819	1711735.547	0.1361	0.2846	0.315468
	446182.455	1711733.56	446182.6635	1711733.221	-.2085	0.3394	0.398327
	446185.678	1711713.696	446185.7658	1711713.463	0.0878	0.2332	0.249181
	446200.725	1711716.06	446200.5843	1711715.79	0.1407	0.2705	0.304904
Average					**0.135**	**0.109**	**0.135**
StDv					**0.191**	**0.239**	**0.191**

Tables.10: Comparison between georeferenced cadastral layer and observed GNSS coordinates

From the investigations and the above comparisons, the following should be taken into account to improve future georeferencing processes and spatial data migration: -

* Khartoum state cadastral land layer has to be further improved.

* High resolution satellite images should be used to investigate other land uses.

From the comparisons carried out in this study, the errors were found to be due to the method of surveying in demarcation of the plots, the setting out and compound walls construction and the Contractors implementation of the construction standards and specifications. All these can be monitored by using active ground control and building management operations.

The Analysis of the results reconfirmed, that, an overall transformation would not produce acceptable results for transferring the mapping data as one block. Also, the results highlighted a number of blocks or zones where the residuals show common systematic orientation and magnitude. The behavior of this function along the boundary between any two Khartoum localities showed that the positional systematic errors in the transformed map data were of the order of 1 meter.

7. Conclusion

The aim of this study is to evaluate and improve Aboadam digital cadastral map and to examine integration possibility with Khartoum and Sudan base maps. The cadastral land maps of the study area evaluated by comparison with Khartoum base map, the result indicated that, there were significant differences in average of errors at easting and northing -0.765m, 0.997m respectively, the standard deviation was 2.602m, 1.223m at both directions respectively. These differences were improved, firstly, by reviewing the digital cadastral land maps

and compared it with the original plan sheet. Secondly, the digital cadastral maps have to be drawn by using AutoCAD software. Thirdly, survey measurements are to be made by GNSS devices to generate the coordinates of the features on the maps by geo-references process (Datum, UTM projection zone 36 N) using ARC GIS software.

Fourthly, after the geo-references process to the digital cadastral maps of Aboadam, Compression was done between these digital cadastral maps and Khartoum and Sudan base maps. The results indicated that there were significant differences in average of errors at easting and northing -0.141m, 0.177m, and -0.005m, -0.121m respectively, and the standard deviations were 0.546m, 0.613m and 0.508m, 0.337m at both directions respectively. Lastly, the comparison of the digital cadastral map features of Aboadam with their corresponding measured values to evaluate the accuracy of geo-reference process, the results indicated that the differences in the average of errors at easting and northing are of the order of 0.135m, 0.109m respectively. The standard deviations were, 0.191m and 0.239m at both directions respectively.

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